The American Holstein dairy cow during early lactation: grazer or browser?

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Introduction

Early lactation in high producing dairy cows has been the focus of extensive research for indoor feeding systems covering an ample range of topics (eg. Thatcher et al., 2006; Van Knegsel et al., 2007; Liu et al., 2009; Robinson, 2010). This volume of scientific information contrasts with the limited and rather recent research on early lactation in high producing grazing dairy cows (Meikle et al., 2004; Kennedy et al., 2007; McEvoy et al., 2008, 2009; Adrien et al., 2010).

Grazing the whole year round represents the dominant feeding system in southern regions of South America like Uruguay, Argentina and Brazil. Major adaptive changes occur during the transition period (3 weeks before and 3 weeks after calving) to cope with the high energy demands of lactation. This transition from pregnant nonlactating state to the nonpregnant lactating state represents a dramatic change for the cow, as nutrient requirements exceed dietary intake potential, and thus a state of negative energy balance is established to provide additional substrate for milk production. The main factor affecting the negative energy balance is dry matter intake (DMI) which under grazing is largely determined by herbage state (Chilibroste et al., 2005). We have studied adaptive changes in grazing behaviour of milking dairy cows related to contrasting feeding strategies (Chilibroste et al., 2007) involving adult and primiparous dairy cows that passed the milk production peak (over 60 days in milk). Just recently we focussed on the transition dairy cow under grazing (Meikle et al., 2004; Chilibroste et al., 2008a,b; Adrien et al., 2010) seeking to integrate adaptive responses of the transition dairy cow at ingestive, digestive, metabolic and endocrine levels.

The metabolic variations that occur during the peripartum period can be monitored by the concentration of some metabolites in blood. Moreover, changes in several metabolites and hormones are thought to be the signals that inform the reproductive axis regarding the energetic status of the animal. While much research has been performed in this area in the last decade in indoor systems of production, the physiological pathways that link this negative energy balance (milk production - intake) with reproduction under grazing systems is still scarce. This is of importance since besides the known gap between demand and requirements during the transition period (Drackley, 1999), grazing cows in the South-American pastoral system do not get sufficient dry matter intake to sustain the high milk production that can be achieved with the available genetic potential (Kolver and Muller 1998). Besides, grazing dairy cows require extra energy to cover the daily 4 ways trip from the milking parlour to the paddock. Our recent research shows that primiparous cows, even if presenting higher BCS during the prepartum period than multiparous cows, present longer anovulatory intervals (Meikle et al. 2004, 2006; Adrien et al. 2010). Although primiparous cows produced less milk, they presented higher non sterified acid concentrations (NEFA), indicating more lipid mobilization and lower insulin-like growth factor I (IGF-I) concentrations than multiparous cows (Meikle et al. 2004). Body condition score at calving (Meikle et al. 2004) and BCS nutritionally regulated at the initiation of the transition period (Adrien et al. 2010) also affected both the blood parameters and the length of anovulatory interval; and this effect was more important in primiparous cows. Overall, the reproductive performance, BCS evolution and the endocrine milieu suggest that the negative energy balance that occurs during the transition period in dairy cows is more severe in primiparous than in multiparous cows under grazing conditions.

The objective of this paper is to establish the influence of herbage allowance on milk production and grazing behaviour of primiparous Holstein dairy cows during early lactation. We do expect with this information to contribute to answer the question raised in the title: "***the Holstein high producing dairy cow in early lactation: behave like a grazer or like a browser ?*** Preliminary reports of this research has been published by Adrien et al., (2008), Chilibroste et al. (2008a,b), Meikle et al., (2008). We are not aware of other studies in this subject involving early lactation primiparous dairy cows.

Materials and Methods

The experiment was carried out at the EEMAC Research Station, Agronomy Faculty, Uruguay (30° S) between March the 8th and June the 7th of 2005. Primiparous dairy cows (n=44, BW= 595±41 kg, age at calving= 2.96±0.11 years and BC=3.7±0.3) were blocked by BW, age and BCS, and randomly assigned from calving up to 60 days in milk to one of the following grazing treatments (n=11 each): high (HA, 30 kg DM cow day^{-1}), medium (MA, 15 kg DM cow day^{-1}) and low ¿herbage? allowance (LA, 5 kg DM cow day^{-1}).

Management and Feeding

Cows were milked at 05:00 and 16:00 h and were allowed to graze between 08:00 and 15:00 h every day on a 7-day rotation schedule on a pasture of Tall fescue (*Festuca arundinacea*), Birdsfoot trefoil (*Lotus corniculatus*) and White clover (*Trifolium repens*). Individual milk production was recorded daily while milk samples were taken during 4 milkings each week and one representative weekly milk sample was analysed for protein, fat and lactose with a milko-scan (Foss Electric®, 133b).

The cows always grazed in adjacent independent plots separated by an electric fence. To achieve the targeted herbage allowance the 11 first calving cows per treatment grazed plots of 1.0, 0.5 and 0.25 ha for HA, MA and LA, respectively. Every week the three treatments were moved to a set of new plots with the same conditions. None of the plots were re-grazed during the experimental period.

All the cows were individually supplemented at 18:00 h with a mixture of corn silage (10 kg) compound feed (4.8 kg) and grass hay (0.4) on a fresh weight basis. The mixture was designed to cover maintenance plus 8-10 l of milk of each individual animal leaving any other difference to pasture intake at grazing.

Pasture determinations

Herbage mass before and after grazing was estimated with a rising plate meter (ASHGROVE) using the double sampling technique (Haydock and Shaw, 1975). Botanical composition of the pasture before and after grazing was assessed by visual observations in a square of 0.3*0.3 m randomly distributed across the plots (12, 6 and 4 replicates for available herbage and 18, 12 and 8 replicates for refused herbage on plots HA, MA and LA, respectively). At each observation point area occupied by grasses, legumes and weeds were determined.

Herbage mass depletion was estimated measuring height with the rising plate for each treatment every hour during the grazing session. The procedure was repeated in weeks 2, 4, 6, 7 and 8 of the experiment.

Grazing behaviour determinations

On weeks 2, 4, 6 and 8 each treatment was observed during three alternate days every 15 minutes and the number of cows grazing, ruminating or in other activities recorded. In the same weeks during three alternate days 4 individual cows from the same block of each treatment were observed. During three grazing sessions of 1 hour bite rate (bites per minute) was counted for each individual cow every 15 minutes. The grazing session started at 08:00 (INITIAL), 10:30 (MIDDLE) and 13:30 h (FINAL).

Other determinations

Blood samples were taken weekly from one month before to two months after calving. Plasmatic levels of total protein, albumin, urea, non esterified acids (NEFA), β-hydroxybutyrate (BHB) and cholesterol, determined every 2 weeks during the experimental period (Meikle et al., 2008).

BCS was registered weekly (scale 1=emaciated, 5=fat, Edmonson et al. 1989) from three weeks previous to the expected calving date till 8 weeks postpartum.

Statistical Design and Analysis

The experiment was run as a completed randomized block design.

Probability of animals grazing, ruminating or in other activities while in the grazing plot was analyzed with a General Lineal Model as repeated measurements in time (GENMOD of SAS v. 8) with the following model:

$$\text{Ln}(P_{ijklm} / (1 - P_{ijklm})) = \mu + \tau_i + \beta_j + \lambda_k + \delta_l(\lambda_k) + \eta_m + (\eta\tau)_{im} + \tau_i\delta_l(\lambda_k) + \delta_l\eta_m(\lambda_k)$$

where:

P_{ijklm} Probability of each activity
M overall mean
$\tau_{i,}$ effect of allowance $_i$
β_j effect of block $_j$
λ_k effect of week $_k$
$\delta_l(\lambda_k)$ effect of day $_l$ within week $_k$
$(\lambda\tau)_{ik}$ interaction between treatment and week
η_m effect of grazing session m
$(\eta\tau)_{im}$ interaction between treatment and grazing session
$\tau_i\delta_l(\lambda_k)$ day effect by treatment within weeks
$\delta_l\eta_m(\lambda_k)$ day effect within grazing session and week

Linear and quadratic effects of days in milk on the dependant variables were tested and differences in slope heterogeneity estimated.

Bite rate of individual cows was analyzed as repeated measurements in time using Proc MIXED of SAS v. 8, with the following model:

$$Y_{ijklm} = \mu + \tau_i + \beta_j + \varepsilon_{ij} + \lambda_k + \varepsilon_{ijk} + \delta_l(\lambda_k) + \tau_i\delta_l(\lambda_k) + \varepsilon_{ijkl} + \eta_m + (\eta\tau)_{im} + \delta_l\eta_m(\lambda_k) + \varepsilon_{ijklm}$$

where:

Y_{ijk} response variable
μ overall mean
τ_i effect of treatment $_i$
β_j effect of block $_j$
ε_{ij} experimental error within experimental units
λ_k effect of week $_k$
ε_{ijk} error of repeated measurement (within experimental units between weeks)
$\delta_l(\lambda_k)$ effect of day $_l$ within week $_k$
$\tau_i\delta_l(\lambda_k)$ day effect by treatment within weeks
ε_{ijkl} error of repeated measurement (within experimental units between days)
η_m effect of grazing session m
$(\eta\tau)_{im}$ interaction between treatment and grazing session
$\delta_l\eta_m(\lambda_k)$ day effect by treatment within weeks
ε_{ijklm} error of repeated measurement (within experimental units between grazing sessions)

For both models (grazing behaviour and intake rate) a first order autoregressive covariance structure was selected.

Results and Discussion

Average weather conditions during the experimental period are shown in Table 1.

Table 1. Weather conditions during the experiment

Week	Mean temperature ºC	Relative Humidity %	Precipitation mm
1	20	73	114
2	18	76	63
3	17	71	1
4	16	67	0
5	18	75	41
6	17	85	145
7	13	74	0
8	15	74	0

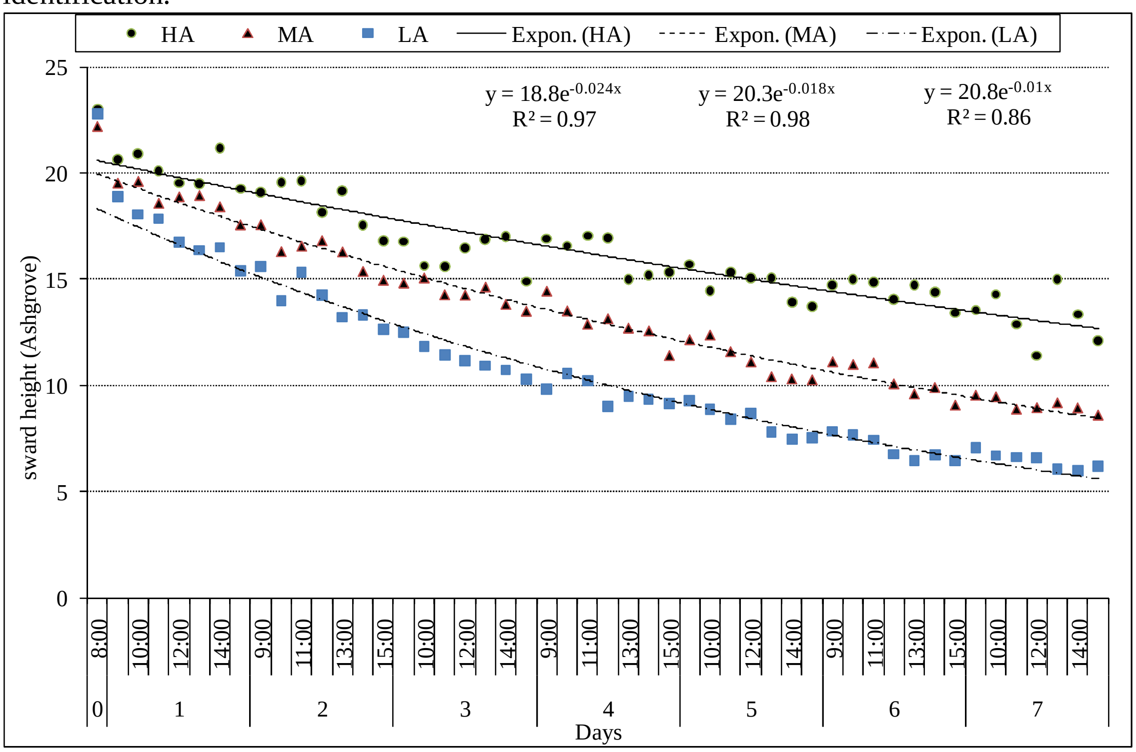
Mean temperature and humidity were relatively high for the autumn season although not limiting for milk production. Rain ranged from 145 mm in week 6 till null in weeks 3, 4, 7 and 8. It seems that the rainy conditions in week 6 did affect milk production in the three treatments (Fig. 2; $p<0.01$) without major observable effects in the other weeks.

Herbage mass and depletion

Mean availability before grazing during the whole experiment was 2750±275 kg DM without significant differences between weeks. The experiment was designed in such a way that height and mass at the end of the plot occupation were different between treatments covering a range from restricted condition for grazing (height below 5-7 cm, LA) to non restricted conditions (height over 10-12 cm, HA). The evolution of height (ASHGROVE) throughout 7 days of the plot occupation and every hour within each day is shown in Fig. 1. height depletion in the three treatments followed an exponential decay with a constant fractional rate of -0.01, -0.018 and -0.024 cm h^{-1} for HA, MA and LA, respectively.

Despite the expected differences between treatments in the constant fractional rate, it is noteworthy that pasture depletion followed the same trend that has been observed on daily strip grazing with or without restrictions on the access time of the cows to the pasture (Chilibroste et al., 2007). In the more intensive treatment (MA and LA) approximately 70 % of the total forage disappeared, disappeared during the first 4 days which is in line with the values reported by Chilibroste et al., (1999) for daily strip grazing management with allowances of 15 kg DM per cow per day. This means that during the first half of the time allocated to each plot the animal faced rapid changes in herbage mass and height, while in the second half, the animals worked in more stable conditions, regardless of whether they are imposed limitations to the harvesting process or not.

Fig. 1. height evolution for high (HA), medium (HM) and low (LA) pasture allowance. Fitted exponential equations for each treatment are shown within the figure under series identification.

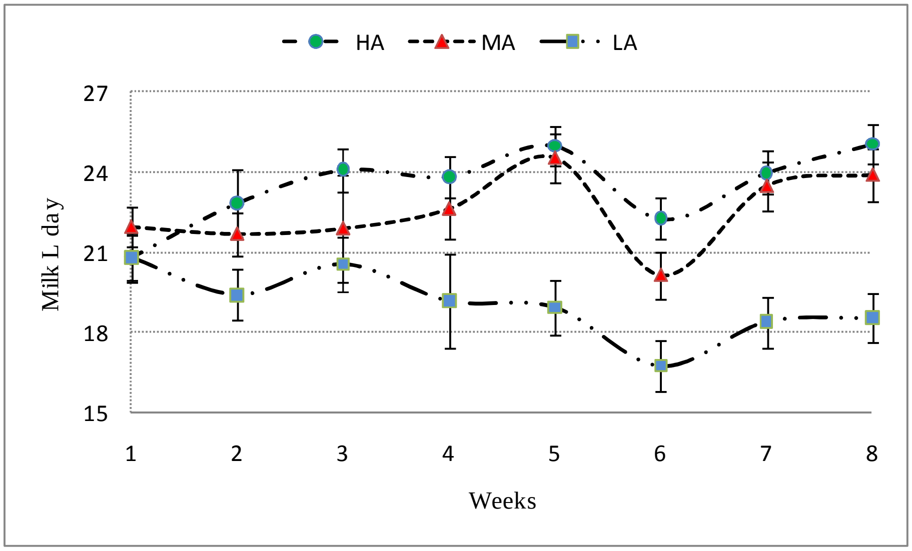


Mean utilization was 47, 61 and 73 % of the initial mass for HA, MA and LA, respectively.

Milk production and composition

The average daily milk production differed (p<0.01) among groups, being highest in the HA group (24.1±0.33 L), followed by MA (22.9±0.42 L) and LA (18.9±0.42 L). The trend in milk production throughout the experimental weeks is shown in Fig. 2. The difference in milk production between treatments is established from the beginning of lactation (week 2). While the difference in milk production between the HA and MA treatments remains similar throughout the experiment, the difference between the higher allowance groups and LA increases with time. Both milk protein and fat content decreased with days in milk (data not shown). Milk protein content (g/kg) did not differ among grazing treatments, while protein yield (kg.cow.day-1) was significantly higher (p<0.01) for HA (0.74±0.019) and MA (0.69±0.024) than for LA (0.56±0.023). No differences were found among grazing treatments for fat content while fat yield (kg cow day) was significantly lower for the LA group (0.89±0.04) than for the HA (1.06±0.03) and MA groups (1.01±0.04), (p<0.01).

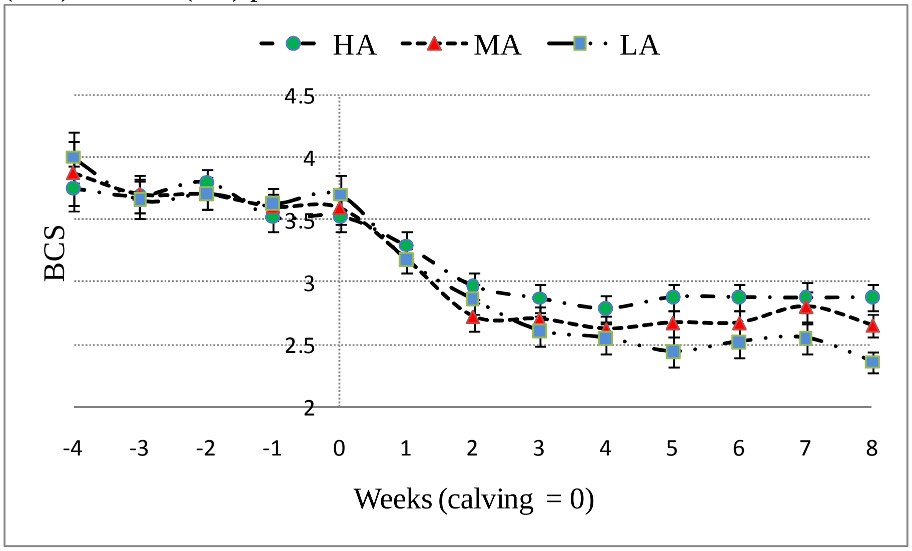
Fig. 2. Milk production for treatments on high (HA), medium (HM) and low (LA) pasture allowance.



Body condition score

The evolution of body condition score of the cows is shown in Fig. 3. It is noteworthy that the prepartum management was able to sustain BCS at calving for all the treatments at a desired level (3.5). Cows in the HA treatment exhibited a significantly higher BCS (3.18±0.03) than cows in the MA and LA treatments (3.05±0.03 and 3.07±0.03; p>0.05). All the treatments mobilize reserves during the first three weeks after calving, but while HA cows lost approximately 0.5 point of BCS, LA cows lost 1 point of BCS besides the lower milk production. Cows in MA treatment tended to lose body condition at a higher rate in the first two weeks postpartum, remaining steady afterwards. These changes were reflected by NEFA levels that increased around calving particularly in the MA group that exhibited significantly higher NEFA level than HA and LA on 15 days postpartum (Meikle et al., 2008). It seems that cows in the MA treatment, although presenting a poorer energy balance than HA cows, were able to mobilize body reserves to sustain similar milk production. Cows in the LA treatment reduced milk production quickly and it remained at lower levels than the other treatments.

Fig. 3. Body condition score (BCS) throughout week for treatments on high (HA), medium (HM) and low (LA) pasture allowance.



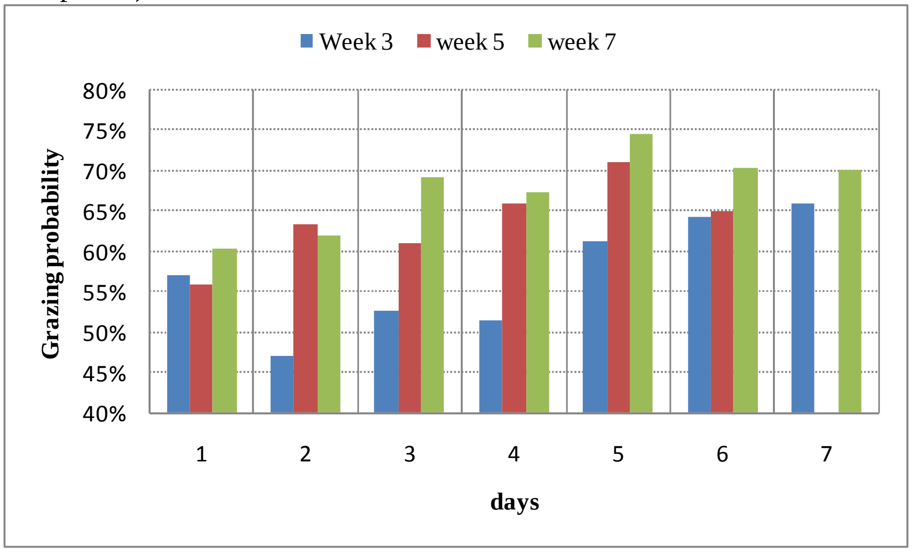
Grazing behaviour

The probability of finding animals in grazing activity was significantly affected by treatment, week, day within week and by interaction treatment by week (p<0.01). Mean values for probability of finding an animal grazing were 59, 65 and 63 % (p<0.05) for HA, MA and LA, respectively. Probability of grazing increases with time being 57, 64, 68 and 71 % during weeks 3, 5, 7 and 8, respectively. Surprisingly, although large differences in evolution of condition (Fig. 1), the probability of grazing was not affected by the interaction treatment by day within weeks, which means that the treatments behave similarly within weeks (Fig. 4). All treatments increased grazing time as grazing progresses in each plot but without a significant interaction treatment by week (p<0.01).

Additionally, we tested the probability of animals grazing during the grazing session: INITIAL, MIDDLE and FINAL. The probability of their being grazing at the initial grazing bout was not significantly different between treatments (86.7, 90.7 and 91.3 % for HA, MA y LA, respectively). At the end of the grazing session the probabilities of grazing were 52, 53, and 61 % for HA, MA y LA, respectively. Despite the larger absolute value of LA compared with HA or MA, differences were not significant between treatments. For all the conditions animals grazed actively at the beginning of the grazing session reducing the activity during the MIDDLE and FINAL grazing bouts.

In our experimental setup time variables like week number and days postpartum are confounded or auto correlated. So we ran an alternative model to study the effect of days in milk (dpp) on grazing activity. By this means we were able to test grazing activity of dairy cows at the beginning of the lactation period as well as test the heterogeneity of slopes between treatments. Treatment effect was not significant (p=0.14) while the linear effect of dpp (p<0.01) and the interaction treatment*dpp (p<0.05) were significant. The estimated probability of one cow being grazing at the beginning of the lactation period was not significantly different between treatments (33.8, 32.5 and 35.0 for HA, MA and LA, respectively), while the slopes for HA and MA treatments (0.39 and 0.44) were significantly higher than for LA (0.22). Despite the differences between treatments it is noteworthy the very low values for grazing time at the beginning of the lactation period. Similar values have been reported for beef heifers (Soca et al., 2008) and Holstein calves (Chilibroste et al., 2008c) exposed to a very selective grazing process.

Fig. 4. Mean grazing probability from day 1 to 7 (start to end of each plot of 7 days occupation).



Along with the evolution of grazing time we counted bite rate on individual cows. All the effects tested in the model were statistically significant ($p<0.01$) except the interaction grazing session by treatment. Mean bite rate were 32.1, 32.7 and 30.0 for HA, MA and LA, respectively. Likewise grazing time bite rate increases along the weeks being 21.8, 29.2, 37.4 and 38.3 for weeks 3, 5, 7 and 8, respectively. Besides, cows grazed at higher rate in the INITIAL grazing bout (44.1 bites/minute) than in the MIDDLE and FINAL (26.9 and 23.8 respectively). Finally, we tested the effect of day in milk (dpp) on bite rate. We detected a significant treatment effect, linear dpp effect and a significant interaction dpp by treatment. While at dpp 0 the mean value for bite rate was around 15 bites per minute the slope was significantly different for HA and MA treatments (0.54 and 0.69 bite per minute per dpp, respectively) than for LA treatment (0.29 bite per minute per dpp). Definitively, the early lactation primiparous cow faced severe restriction to fulfilment of required energy under grazing conditions. Primiparous cows stay in grazing activity a very low proportion of the allowed grazing time (< 35 %) and at a very low rate (less than 25 bites per minute) which suggests a slow and probably very selective grazing process. It seems that it takes at least three weeks for the animals to achieve higher values comparable with those reported in the literature (Chilibroste et al., 2005). This research suggests that differences between treatments in DMI must be related to significant differences in bite mass according to the condition faced in each treatment. Herbage mass, height, density, spatial distribution, etc. probably play a major role in this adaptation process. Recent research in this area (Kennedy et al., 2007; McEvoy et al., 2008) suggests that low to medium allowances will be enough to cover requirements of early lactation dairy cows. Our research does not agree with this conclusion. The lack of responses to higher levels of herbage allowance seems to be related to the low adaptation capability to the harvesting process of the grazing early lactation cow (especially primiparous) rather than low or fulfilled requirements.

Conclusions

Early lactation first calving dairy cows exhibited a grazing pattern characterized by low grazing activity and intake rate. Both parameters increased linearly from calving till day 60 postpartum. ***The grazing pattern exhibited by the cows resembles more a browser, than a grazer foraging behavior***. Further research is required to determine the animal, pasture and/or management inherent factors and their interactions that may help the adaptation process of early lactation Holstein grazing dairy cows.

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